ISSN 1980-5411 (On-line version)
Production, 33, e20230035, 2023
DOI: 10.1590/0103-6513.20230035

Research Article

Prioritisation of criteria for sustainable and agile global manufacturing outsourcing partner selection using simulation based stochastic fuzzy PIPRECIA method

Mohammad Akhtar[a*]

[a]School of Business, Galgotias University, Greater Noida, Uttar Pradesh, India

*mk71b@yahoo.com

Abstract

Paper aims: To develop an effective and novel decision making method to assess the strategic priority of the criteria for sustainable and agile global manufacturing outsourcing partner (GOP) selection

Originality: The PIPRECIA Simplified method using random number based stochastic and triangular fuzzy number is applied for setting priority of the GOP selection criteria

Research method: Sustainable and agile criteria were adopted for global manufacturing outsourcing partner selection from the literature review and discussion with industry experts. Criteria weight and strategic priority was determined using a novel stochastic fuzzy PIPRECIA Simplified method using triangular fuzzy number and random number based uniform distribution of each criterion minimum-maximum ratings. This method will overcome the impreciseness, uncertainty and randomness in subjective group rating.

Main findings: Customer driven innovation, worker's training and career development, multi-skilled and flexible workforce, delivery flexibility, collaboration with partners, green manufacturing process, and worker's occupational health and safety are found to be the most important criteria in GOP selection in footwear industry. Main criteria in decreasing order of strategic priority are agile, social, environmental and economic.

Implications for theory and practice: The proposed novel method was applied with a case study of footwear industry to determine the criteria weight and priority, which will enhance supply chain agility and sustainability. The managers in the footwear industry can use the agile and sustainable criteria and proposed method easily.

Keywords

Global manufacturing outsourcing partner selection. Sustainable and agile outsourcing criteria. Fuzzy PIPRECIA. Simulation based stochastic model. Footwear industry.

How to cite this article: Akhtar, M. (2023). Prioritisation of criteria for sustainable and agile global manufacturing outsourcing partner selection using simulation based stochastic fuzzy PIPRECIA method. *Production*, *33*, e20230035. https://doi.org/10.1590/0103-6513.20230035

Received: May 17, 2023; Accepted: Oct. 20, 2023.

1. Introduction

Supply chain management (SCM) is important for firms control the raw materials procurement, transportation, storage, inventory and finished goods distribution to fulfill customer orders. It is a great approach for the companies for improving competitiveness and cutting down operating costs. Outsourcing manufacturing activities to an external company or a contract manufacturer is advantageous and effective way to increase the profit as well as the flexibility of production capability and reduce the operational cost. Global outsourcing offers additional benefits of access to newer product design, latest technology, and cost competitiveness. The selection of global manufacturing outsourcing partner (GOP) is essential and crucial for a company to select appropriate contract manufacturers that influence upstream, downstream and reverse supply chain operations for firm's competitive advantage.

Coordination with outsourcing partners will integrate business processes and manage customers (Prakash & Barua, 2016). Supply chain (SC) managers have been able to boost competitive positions of the company and incorporate sustainability through contract manufacturing partnership (Govindan et al., 2014; Luthra et al., 2017). Sustainable SCM is considered to achieve environmental efficiency and social responsibility (Gualandris et al., 2014). Supply chain practices such as customer relationships, postponement, information quality and sharing influences environmental sustainability that have significant direct impact on financial performance (Jum'a et al., 2021). Le & Ikram (2022) discovered a substantial positive association between sustainability innovation and company competitiveness, while the latter had a large positive relationship with financial, environmental, and operational performance. Intensified emphasis on sustainability in recent times has increased pressure to select the best sustainable supplier and contract manufacturer. Companies should select sustainable contract manufacturing partners to fulfill customers' requirements, social commitments and regulations (Govindan et al., 2014) and consider economic, environmental and social sustainability criteria to evaluate outsourcing partners' performances to achieve sustainable business practices (Govindan et al., 2014). Businesses must guide their partners in aspects of green and technical advances, sustainable and environmental management, and social obligations (Luthra et al., 2017). Companies are required to collaborate with their SC partners to enhance operational efficiency and SC agility (Wu & Barnes, 2011).

In any country, footwear industry is crucial. India is the second largest footwear producer of different variety of footwear. Footwear are produced in exceptionally large quantities; having shorter product life due changing fashion trends and the manufacturing is mostly labour-oriented employing millions of laborers in a developing country like India. Footwear manufacturing and end of life cycle impacts environment as it uses plastics, rubbers, chemicals. Fossil's fuel is used to run the manufacturing machines that produce greenhouse gases. India is second global footwear producer accounting for 11.63% of global footwear production. The footwear industry is very competitive and the business environment is uncertain and volatile. Owing to environmental and social awareness, and global pressure, the firms are committed to follow sustainable supply chain. Hence, the study in Indian context is more relevant.

Though large number of studies on outsourcing partner selection studies is found in the literature, few studies are related to GOP selection. Majority of the studies considered economic and operational criteria while limited studies adopted agile, environmental and social sustainability criteria. The study on GOP selection with agile and triple bottom line sustainability criteria in footwear industry in a developing economy context is lacking. Thus, following research questions are framed:

RQ1: What are the important agile and triple bottom line (economic, environmental and social) sustainability criteria for evaluation of GOP in a developing economy context?

RQ2: Which suitable technique to be applied for determining the criteria weight and priority?

RQ3: Which theory should be applied to overcome the impreciseness, ambiguity and uncertainty in group ratings?

To answer the above research questions, study in conducted as follows. The agile and sustainable criteria for GOP selection are identified based on the literature review and discussion with industry experts in a developing economy context. PIvot Pairwise RElative Criteria Importance Assessment Simplified (PIPRECIAS) is applied to determine weight and rank of the GOP selection criteria. Triangular fuzzy sets have been extended to PIPRECIAS method to overcome the impreciseness and uncertainty in subjective rating of criteria relative importance by group of decision makers (DM). To improve the accuracy of the assessment, simulation based stochastic process is also applied.

The paper is arranged as follows. Section two highlights the literature review, section three describes the methodology, section four demonstrates the case study of footwear company, section five presents analysis and result, section six provides discussion on the findings and implications, and the section seven offers conclusion, limitations and future research.

2. Literature review

Business firms outsource non-core activities to outside party or contract manufacturer to so as to increase productivity and profit, and focus on the core activities. It helps in producing products more efficiently and thus gaining competitive advantages. Globalization, increasingly customer demand, new technologies have provided manufacturing outsourcing opportunities. The right outsourcing partner selection significantly reduces purchasing costs and enhances the customer satisfaction and market competitiveness. Dependable and robust supplier evaluation improves quality, delivery, flexibility and cost savings (Govindan et al., 2014), innovation and maintaining high service levels (Nair et al., 2015). Supplier and vendor selection influences supply chain operations and performance (Malviya et al., 2018).

2.1. Selection criteria for global manufacturing outsourcing partner

Right criteria selection is a key aspect in manufacturer outsourcing. It is imperative for decision-makers (DMs)to identify selection criteria and evaluate partner's compatibility and feasibility prior to outsourcing. Garg & Sharma (2020) considered environmental factors (green practices and packaging, energy efficiency and cleaner technology, emission minimisation, green certification and accreditation, waste minimization, green manufacturing and marketing, green purchasing and designing, reverse logistics), economic factors (firm performance and reputation, outsourcing cost, service delivery, financial and resources capacity, technical and communication ability) and social factors (rights to employees and fair wages, working conditions and health, social welfare and development, safety, equity, ethical practices, women specific issues, community connection and support) for sustainable outsourcing partner selection. Development of workers' skills and knowledge and their long term career growth should be prioritized in sustainable outsourcing (Faisal et al., 2017). Workers training and career development enhances their knowledge and skills leading to improvement of working condition and job satisfaction in manufacturing outsourcing (Rahman & Subramanian, (2017).

Quality, costs, delivery and price are the most significant criteria considered whereas environmental, social and economic criteria are considered for sustainable supplier selection (Vasiljević et al., 2018) that will help in achieving long-term ecological stability and business sustainability (Sen et al., 2018). Environmental costs, green design and purchasing, occupational health & safety systems, green management, green R&D and innovation, technological & financial capability, the rights of stakeholders, waste management and pollution prevention, production facilities and capacity, lead time required, quality of product, environmental competencies, transportation cost, information disclosure, profit on product, environment management systems, price of product, green manufacturing, green packing and labeling, delivery and service of product, the interests & rights of employees and flexibility criteria (Luthra et al., 2017). Global risk, social, economic, quality and environment criteria for sustainable supplier selection (Awasthi et al., 2018). Financial situation, green image, technology capability service, social responsibility management system, quality, pollution control, delivery reliability, pollution production, green product, health and safety contractual, stakeholder influence, local community influence, environmental management system and cost (Sinha & Anand, 2018). Goren (2018) proposed lead time, productivity, price, responsiveness, capacity of the supplier, resource consumption, quality, long-term relationship, green product design, production technology, supportive activities, environmental management system, occupational health and safety management system. Fallahpour et al. (2017) identified quality (process for internal quality audit of material, capability of handling abnormal quality, rejection rate of the product), cost (freight cost, after-sales service cost, material cost), flexibility (flexibility of delivery time, flexibility in giving discount, flexibility in ordering), and delivery & service (on-time delivery, after-sales service, time to solve the complaint, lead time flexibility). Arabsheybani et al. (2018) considered cost, quality, delivery, green supply chain, environmental management system, worker safety and health, rights of employee. Song et al. (2017) chose 10 criteria; occupational health and safety, delivery, environmental management system, employee right and welfare, resource consumption, eco-design, reduce, reuse and recycle (3R), cost/price (profitability of suppliers), training and community development and quality. Ulutas et al. (2016) adopted late delivery percentage, supplier production capacity, technological capability, reputation, communication issues, cost, financial position, volume flexibility, order requirement, compliance with sectoral price and defect percentage as criteria for supplier selection. Cheraghalipour & Farsad (2018) considered economic (loyalty, quality, service, cost, delivery, cost, technology, financial situation), environmental (product performance, environmental pollution, environmental management& commitment) and social (wages and working hours, worker occupational health& safety, social management &commitment, freedom of association).

Criteria for agile contract manufacturer selection, Adali & Işık (2017) adopted product cost, delivery on time, reliability, material quality, production capacity, production equipment, and geographic location. Hu & Yu (2015) considered cost, delivery, quality and flexibility. Various studies on SC agility has been conducted across wide range of industries; oil and gas (Yusuf et al., 2014), electronics industry using Delphi method, ANP and DEMATEL (Wu et al., 2017), fashion and textiles (Chan et al., 2017), and manufacturing industries (Al-Shboul, 2017). Supply chain agility and resilience impact supply chain performance (Barhmi, 2019).

Various MCDM techniques such as AHP, BWM, CRITIC, Shannon entropy, SWARA, PIPRECIA, ITARA, factor rating, Coefficient of variance etc. have been applied to determine criteria weight and ranking in outsourcing partner selection. CRITIC method (Adali & Işık, 2017; Liaw et al., 2020); neutrosophic sets based MABAC (Ji et al., 2018); fuzzy SWARA (Percin, 2019); BWM (Garg & Sharma, 2020); intuitionistic fuzzy cognitive map (Goker, 2021); AHP (Singh & Sarkar, 2021); neutrosophic ITARA (Lo et al., 2022); ANP and AHP (Sahu et al., 2023) for criteria weight determination in outsourcing decisions.

The PIPRECIA method (Stanujkic et al., 2017) has found many applications in the literature. Fuzzy PIPRECIA method was applied to evaluate all elements of SWOT in information technology implementation in warehouse system (Stević et al., 2018); fuzzy PIPRECIA and interval rough SAW model for green supplier selection (Đalić et al., 2020); fuzzy PIPRECIA and fuzzy EDAS model for selection of best business solution of passenger rail operator (Vesković et al., 2020); entropy, fuzzy PIPRECIA and DEA model for railway traffic safety evaluation (Blagojevic et al., 2020); fuzzy Preference Selection Index (PSI), PIPRECIA and CoCoSo for the transportation company selection (Ulutaş et al., 2021) and fuzzy PIPRECIA method to assess causes of delays in road construction projects (Stević et al., 2022).

Stochastic version of MCDM models have also been developed to overcome the randomness in group decision making. Jalao et al. (2014) proposed beta stochastic pair wise comparisons in AHP and a non-linear programming model to compute weights, which maximize the preferences. Ayrim e al. (2018) adopted stochastic COPRAS for selection of cargo transportation firm to overcome the limitations of the traditional and fuzzy MCDM approach. Stochastic version such as Monte Carlo simulation based AHP and other MCDM methods were used for the offshore wind turbine selection (Kolios et al., 2016a). Stochastic TOPSIS using simulation based on normal distribution proposed for optimum support structural configuration selection for offshore wind turbines (Kolios et al., 2016b). Stochastic fuzzy TOPSIS using mean and standard deviation for vendor selection (Akhtar & Ahmad, 2021).

The PIPRECIA is simple, easy to implement and provides accurate criteria weight. It does not require presorting of criteria. Stević et al. (2018) proposed fuzzy version (F-PIPRECIAS) to overcome the ambiguity and uncertainty in group rating. In practice, criteria are rated by few DMs. The performance of evaluation process increases when the number of DMs increases. Therefore, simulation based stochastic version of fuzzy PIPRECIAS is proposed in this paper to determine the selection criteria weight and rank for GOP with a case application in Indian footwear industry.

3. Methodology

The global manufacturing outsourcing partner evaluation and selection process is a multi criteria decision making problem, in which criteria and alternatives ratings are carried out by group DMs. For the criteria weight and rank determination, the research methodology is shown in Figure 1.

Stanujkic et al. (2017) proposed PIPRECIA method in which criteria sorting are not required and every successive criterion is rated with respect to previous criteria. This is improvement over Step-wise Weight Assessment Ratio Analysis (SWARA) method developed by Kersuliene et al. (2010) in which the criteria evaluation is done in two stages. First criteria is rated in terms of expected significance and sorted. Then, sorted criteria are rated in terms of relative importance. In AHP large number of mutual comparison is required. In BWM, criteria relative ratings are done with respect to best criteria and also with respect to worst criteria. PIPRECIA method is simple to use and provides consistent results. Stević et al. (2018) proposed a fuzzy version (F-PIPRECIA) to overcome the difficulties of impreciseness, ambiguity and uncertainty inherent in group decision making. Stanujkic et al. (2021) proposed simplified version (F-PIPRECIAS), in which all the criteria starting from second are rated for relative importance with respect to the first criteria. F-PIPRECIAS is easy to use, overcomes the shortcomings of AHP, BWM and SWARA, and provides accurate results (Ulutaş et al., 2021). In MCDM method, number of expert is limited and their opinions are random and consensus may not exist, which can introduce a bias and reducing the confidence of the qualifying solution. Based on limited experts rating, stochastic values are calculated using random numbers, which will enhance the confidence level to determine consensus of the expert opinions (Kolios et al., 2016b). The author proposes simulation based stochastic fuzzy PIPRECIA simplified (SF-PIPRECIAS) method for subjective weights determination and ranking of selection criteria for the GOP in this paper.

3.1. F-PIPRECIAS

Step 1: Determine the selection criteria and the Decision Maker (DMs).

Step 2: Rate the criteria for its relative importance (sj) in linguistic terms:

The criteria are rated for its relative importance (sj) by group of DMs, except the first, starting from the second criterion in linguistic scale using Table 1 or Table 2. All the criteria are compared with criterion one. If the criterion is of greater importance in relation to the criterion one, use the fuzzy scale in Table 1. On the other hand, if the criterion is of lesser importance compared to the criterion one, use the fuzzy scale in Table 2. Fuzzy number x is demoted by triangular number x (l, m, u).

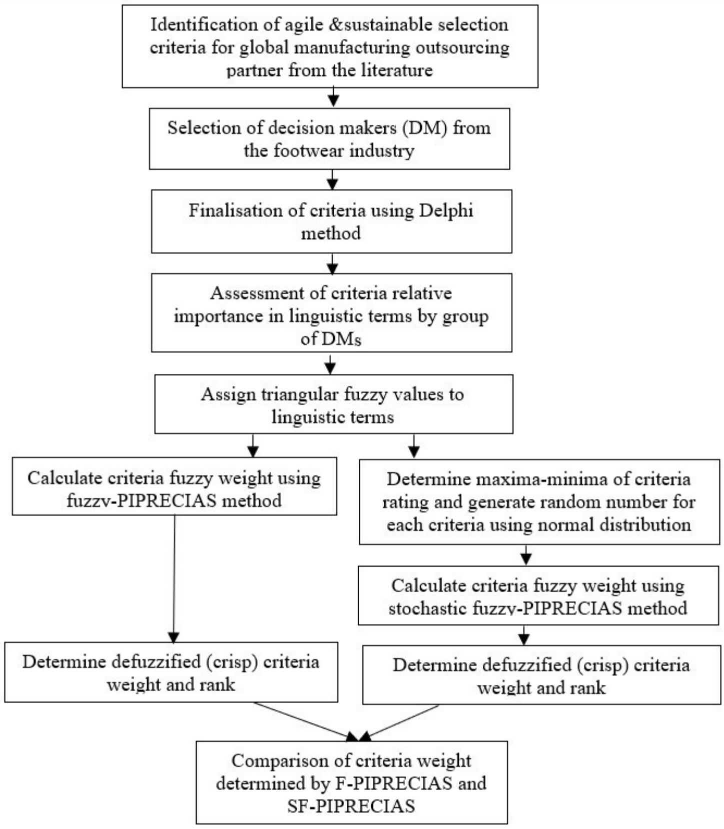

Figure 1. Proposed Research Methodology.

Table 1. Fuzzy 1-2 Scale for Assessment of the Criteria.

Linguistic Scale	Triangular Fuzzy Number (TFN)		
	l	*m*	*u*
Almost equal significant (AE)	1.000	1.000	1.050
Slightly more significant (SM)	1.100	1.150	1.200
Moderately more significant (MM)	1.200	1.300	1.350
More significant (M)	1.300	1.450	1.500
Much more significant (MR)	1.400	1.600	1.650
Dominantly more significant (DM)	1.500	1.750	1.800
Absolutely more significant (AM)	1.600	1.900	1.950

Adopted from Stević et al. (2018).

Table 2. Fuzzy 0-1 Scale for Assessment of the Criteria.

Linguistic Scale	Triangular Fuzzy Number (TFN)		
	l	*m*	*u*
Weakly less significant (WL)	0.667	1.000	1.000
Moderately less significant (MDL)	0.500	0.667	1.000
Less significant (L)	0.400	0.500	0.667
Really less significant (RL)	0.333	0.400	0.500
Much less significant (ML)	0.286	0.333	0.400
Dominantly less significant (DL)	0.250	0.286	0.333
Absolutely less significant (AL)	0.222	0.250	0.286

Adopted from Stević et al. (2018).

$$\overline{s_j^r} = \begin{cases} > \overline{1}, & if\ C_j > C_{j-1} \\ = \overline{1}, & if\ C_j = C_{j-1} \\ < \overline{1}, & if\ C_j < C_{j-1} \end{cases} \tag{1}$$

where, C_j and C_{j-1} denote the significance of criterion *j* and criterion *j*-1, respectively; and S_j^r denotes the relative importance of criteria *j* by r^{th} DM.

Step 3: Assign triangular fuzzy value to linguistics terms using Table 1 and 2.

Step 4: Determine average fuzzy rating by taking geometric mean (G.M.).

$$\overline{S_j} = \prod_{j=1}^{n} S_j \tag{2}$$

Step 5: Determine the coefficient (k_j):

$$\overline{k_j} = \begin{cases} \overline{1}, & if\ j = 1 \\ 2 - \overline{S}_j, & if\ j > 1 \end{cases} \tag{3}$$

Step 6: Determine criteria fuzzy recalculated weight (q_j):

$$\overline{q}_j = \begin{cases} 1, & if\ j = 1 \\ \dfrac{1}{k_j}, & if\ j > 1 \end{cases} \tag{4}$$

Step 7: Determine the criteria fuzzy relative weights:

$$\overline{w}_j = \frac{\overline{q}_j}{\sum_{j=1}^{n} \overline{q}_j} \tag{5}$$

Where, n denotes the number of the criteria.

Step 8: Determine the criteria defuzzified relative weights as:

$$\text{Wj} = \frac{\left(\text{Wl}^{-} + 4{*}\text{Wm}^{-} + \text{Wu}^{-}\right)}{6} \tag{6}$$

3.2. SF-PIPRECIAS

To overcome the disadvantage of less number of DMs rating the criteria, SF-PIPRECIAS is proposed in which random numbers are generated based on uniform distribution. The steps are given below:

Step 1 to 3 are same as F-PIPRECIAS.

Step 3A: Determine the minimum and maximum rating for each criterion. Then generate the random numbers for each criterion from uniform distribution in a minimum-maximum range.

Remaining *steps* (step 4 to Step 8) remain same.

4. Case study of a footwear company

The Indian Footwear company started its operation in 70s which produces light weight slippers, canvas shoes and hawai slippers for masses in domestic market. Its turnover rose from INR 250K in 1971 to around INR 20 billion in 2019. It produces sports shoes, non-leather slippers, sandals in manufacturing plants at ten locations in India. The company has now expanded its range of products into non-leather and leather based high end formal shoes, sandals and slippers for ladies and footwear for kids. Raw materials required are Polyurethane and Ethylene-Vinyl Acetate for sole, flynet, adhesive chemicals, rubber, and fabrics. The manufacturing and end of footwear life cycle impacts environment. The business environment of footwear industry is very competitive in India and business environment is volatile. Hence, the firm started global outsourcing for product design and manufacturing from China, Vietnam, Cambodia, Indonesia and Sri Lanka. The firm is selling the product in the country as well as exporting to Middle East and African countries. Indian footwear industry, need to consider agile, economic, environmental and social sustainability criteria in global manufacturing outsourcing partner selection to meet global environmental concern and competitiveness. The study will help to set priority for the criteria and factors that need to be given more consideration over others in GOP. The proposed research framework is shown in Figure 1.

4.1. Identify selection criteria and DMs

From the literature, twenty-four factors (criteria) including economic, sustainable and agile for GOP were identified. Five procurement experts from the footwear company participated in the Delphi process. After discussion with Delphi members, the nineteen criteria were finally selected which are coded as AG1,...AG8, EN1,...EN4, SO1,...SO4, EC1,...EC3 as displayed in Table 3. The respondents or DM were selected using snowball sampling from the footwear company, possessing more than five years of contract management and vendor development experience and consented to participate in the survey.

4.2. Data collection

The questionnaire was prepared to collect data from DMs. The part-A of the questionnaire is the DM's profile such as name (optional), position, years of experience in SC, company name, email etc. while in part-B the DMs were asked to rate the identified nineteen criteria in linguistics terms using the Table 1 and Table 2. The questionnaire was emailed and ten valid responses were received after follow ups. Respondents/decision maker are coded as D1, D2,...,D10. Valid responses are few as the survey was done at a firm level.

5. Analysis and result

5.1. Criteria weight by F-PIPRECIAS

Criteria relative importance rating (s_j) in linguistic terms by ten DEs is shown in Table 4. Then TFN values were assigned to linguistic terms from Table 1 and 2 as shown in Table 5. Geometric mean of fuzzy relative importance ($\bar{s}_j$) was calculated using Equation 2 to get aggregated matrix as shown in Table 6. Fuzzy coefficient ($k_{\bar{j}}$), fuzzy recalculated weights ($q_{\bar{j}}$) and fuzzy relative weights ($w_{\bar{j}}$) were obtained using Equations 3, 4 and 5 respectively as shown in Table 6. The criteria defuzzified relative weights (F-Weight) was obtained using Equation 6 as shown in Table 6 and Figure 2.

5.2. Criteria weight by SF-PIPRECIAS

The minimum and maximum relative importance rating for each criterion was determined. Then 100 random numbers were generated in MS-Excel using RANDBETWEEN function for each criterion from a uniform distribution in a minimum-maximum range and geometric mean of fuzzy relative importance ($\bar{s}_j$) is shown in Table 7. Criteria fuzzy relative weights (w^{-}_{j})was calculated using Equation 5. Criteria defuzzified relative weights (SF-Weight) was obtained using Equation 6 as shown in Table 7.

A comparison of criteria weight and rank by F-PIPRECIAS and SF-PIPRECIAS are shown in Table 8 and Figure 3 and 4.

6. Discussion on the findings

The business environment is more volatile and uncertain due to disruption. The manufacturing supply chains are becoming global from sourcing to consumer. The footwear industry, in particular, faces challenges such as competitive global markets, increased product variety, shorter product life cycles, and fast and responsive customer service. Such companies are going for manufacturing outsourcing. It has become imperative to adopt agility and sustainability to be more resilient and competitive. Therefore agile and sustainable criteria in addition to economic and efficiency criteria for sustainable and agile global manufacturing outsourcing partner selection to be adopted.

Table 3. Agile and Sustainable Criteria for GOP selection from the literature.

Criteria Category	Criteria Code	Criteria	Benefit/Non-benefit	Description	References
Agile Criteria	AG1	Production flexibility & capability	Benefit	The ability to produce variety of products in the quantities that customers demand.	Ulutas et al. (2016), Luthra et al. (2017), Adalı & Işık (2017), Awasthi et al. (2018), Goren (2018)
	AG2	Service level	Benefit	Providing service without stock-out situation	Ulutas et al. (2016), Awasthi et al. (2018), Garg & Sharma (2020), Kabus et al. (2022).
	AG3	Lead time minimisation	Benefit	Lead time minimisation	Luthra et al. (2017), Goren (2018)
	AG4	Delivery flexibility	Benefit	The ability to exploit various dimensions of delivery	Ulutas et al. (2016), Luthra et al. (2017), Adalı & Işık (2017), Awasthi et al. (2018), Garg & Sharma (2020)
	AG5	Sourcing flexibility	Benefit	The availability of range of sourcing options	Luthra et al. (2017), Garg & Sharma (2020)
	AG6	Multi-skilled and flexible workforce	Benefit	Multi-skilled workforce will provide flexibility in scheduling workers	Ulutas et al. (2016)
	AG7	Collaboration with partners	Benefit	Collaboration with suppliers will enhance innovation and capability	Ulutas et al. (2016), Luthra et al. (2017), Awasthi et al. (2018), Goren (2018), Garg & Sharma (2020)
	AG8	Customer driven innovation	Benefit	Customer need-based innovation	Sinha and Anand (2018).
`Environmental Criteria	EN1	Green product	Benefit	Product requiring less physical resources and low environmental impacts	Luthra et al. (2017), Awasthi et al. (2018), Sinha & Anand (2018)
	EN2	Green manufacturing process	Benefit	Manufacturing process that minimise waste, pollution, and energy use.	Luthra et al. (2017), Awasthi et al. (2018), Sinha & Anand (2018), Garg & Sharma (2020)
	EN3	Cleaner Technology	Benefit	Technology and processes that use renewable energy and minimises resource use, waste and emission.	Luthra et al. (2017), Awasthi et al. (2018), Sinha & Anand (2018), Garg & Sharma (2020)
	EN4	Environmental Management System (EMS)	Benefit	Planning, implementation, monitoring and controlling environmental protection	Luthra et al. (2017), Awasthi et al. (2018), Sinha & Anand (2018), Garg and Sharma (2020),
Social Criteria	SO1	Worker's fair wages and welfare	Benefit	Workers' wages and welfare at supplier's firm	Luthra et al. (2017), Garg & Sharma (2020),
	SO2	Worker's occupational health and safety	Benefit	Workers' occupational health and safety at suppliers' firm	Sinha & Anand (2018), Luthra et al. (2017), Garg & Sharma (2020),
	SO3	Worker's training and career development	Benefit	Workers skill and career development	Rahman & Subramanian (2017), Faisal et al. (2017)
	SO4	Corporate Social responsibility	Benefit	Social welfare and community development	Awasthi et al. (2018), Sinha & Anand (2018), Garg and Sharma (2020)
Economic Criteria	EC1	Product price	Non-benefit	Product price	Ulutas et al. (2016), Luthra et al. (2017), Adalı & Işık (2017), Awasthi et al. (2018), Sinha & Anand (2018), Garg & Sharma (2020), Kabus et al. (2022)
	EC2	Product quality	Benefit	Cost reduction	Ulutas et al. (2016), Luthra et al. (2017), Adalı & Işık (2017), Awasthi et al. (2018), Goren (2018), Sinha & Anand (2018),
	EC3	Cost Reduction	Benefit	Product quality and reliability	Ulutas et al. (2016), Luthra et al. (2017), Adalı & Işık (2017), Awasthi et al. (2018), Sinha & Anand (2018)

Table 4. Criteria Relative Importance Rating in Linguistic Terms by DMs.

Criteria	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10
AG1										
AG2	MM	MM	AM	DM	MM	MM	SM	MM	DM	M
AG3	WL	M	WL	MR	AM	M	MR	MM	AE	M
AG4	DM	MR	AM	MM	MM	M	MR	M	DM	DM
AG5	DM	SM	DM	AM	M	AE	MM	M	M	AE
AG6	AM	MR	MR	DM	AM	M	M	MR	M	MR
AG7	WL	MR	DM	DM	DM	MR	DM	DM	DM	MM
AG8	MR	AM	AM	AM	SM	AM	DM	DM	DM	AM
EC1	AM	MR	MDL	WL	WL	WL	MDL	AE	WL	WL
EC2	DM	WL	WL	MDL	DM	MDL	WL	WL	MDL	AE
EC3	MM	MDL	MR	M	WL	AE	MM	MM	WL	WL
EN1	MDL	AE	WL	WL	DM	MDL	WL	WL	WL	MDL
EN2	DM	MR	MM	M	AM	M	MR	MM	DM	MR
EN3	SM	MR	MR	DM	WL	MR	M	MM	M	M
EN4	WL	M	AM	M	MM	MM	M	M	MM	MM
SO1	DM	MM	MM	MR	DM	WL	AE	MM	AE	WL
SO2	WL	M	MR	DM	MR	MR	DM	DM	MR	MR
SO3	MR	MR	AM	MR	DM	MR	M	DM	AM	DM
SO4	M	M	M	M	MDL	M	MR	MR	M	M

Table 5. Criteria Relative Importance Fuzzy Rating (s_j) by DMs.

Criteria	D1			D2			D3			D4			D5			D6			D7			D8			D9			D10		
AG1																														
AG2	1.2	1.3	1.35	1.2	1.3	1.35	1.6	1.9	1.95	1.5	1.75	1.8	1.2	1.3	1.35	1.2	1.3	1.35	1.1	1.15	1.2	1.2	1.3	1.35	1.5	1.75	1.8	1.3	1.45	1.5
AG3	0.667	1	1	1.3	1.45	1.5	0.667	1	1	1.4	1.6	1.65	1.6	1.9	1.95	1.3	1.45	1.5	1.4	1.6	1.65	1.2	1.3	1.35	1	1	1.05	1.3	1.45	1.5
AG4	1.5	1.75	1.8	1.4	1.6	1.65	1.6	1.9	1.95	1.2	1.3	1.35	1.2	1.3	1.35	1.3	1.45	1.5	1.4	1.6	1.65	1.3	1.45	1.5	1.5	1.75	1.8	1.5	1.75	1.8
AG5	1.5	1.75	1.8	1.1	1.15	1.2	1.5	1.75	1.8	1.6	1.9	1.95	1.3	1.45	1.5	1	1	1.05	1.2	1.3	1.35	1.3	1.45	1.5	1.3	1.45	1.5	1	1	1.05
AG6	1.6	1.9	1.95	1.4	1.6	1.65	1.4	1.6	1.65	1.5	1.75	1.8	1.6	1.9	1.95	1.3	1.45	1.5	1.3	1.45	1.5	1.4	1.6	1.65	1.3	1.45	1.5	1.4	1.6	1.65
AG7	0.667	1	1	1.4	1.6	1.65	1.5	1.75	1.8	1.5	1.75	1.8	1.5	1.75	1.8	1.4	1.6	1.65	1.5	1.75	1.8	1.5	1.75	1.8	1.5	1.75	1.8	1.2	1.3	1.35
AG8	1.4	1.6	1.65	1.6	1.9	1.95	1.6	1.9	1.95	1.6	1.9	1.95	1.1	1.15	1.2	1.6	1.9	1.95	1.5	1.75	1.8	1.5	1.75	1.8	1.5	1.75	1.8	1.6	1.9	1.95
EC1	1.6	1.9	1.95	1.4	1.6	1.65	0.5	0.667	1	0.667	1	1	0.667	1	1	0.667	1	1	0.5	0.667	1	1	1	1.05	0.667	1	1	0.667	1	1
EC2	1.5	1.75	1.8	0.667	1	1	0.667	1	1	0.5	0.67	1	1.5	1.75	1.8	0.5	0.667	1	0.67	1	1	0.67	1	1	0.5	0.67	1	1	1	1.05
EC3	1.2	1.3	1.35	0.5	0.67	1	1.4	1.6	1.65	1.3	1.45	1.5	0.667	1	1	1	1	1.05	1.2	1.3	1.35	1.2	1.3	1.35	0.667	1	1	0.667	1	1
EN1	0.5	1.75	1.8	1	1	1.05	0.667	1	1	0.667	1	1	1.5	1.75	1.8	0.5	0.667	1	0.67	1	1	0.67	1	1	0.667	1	1	0.5	0.67	1
EN2	1.5	1.75	1.8	1.4	1.6	1.65	1.2	1.3	1.35	1.3	1.45	1.5	1.6	1.9	1.95	1.3	1.45	1.5	1.4	1.6	1.65	1.2	1.3	1.35	1.5	1.75	1.8	1.4	1.6	1.65
EN3	1.1	1.15	1.2	1.4	1.6	1.65	1.4	1.6	1.65	1.5	1.75	1.8	0.667	1	1	1.4	1.6	1.65	1.3	1.45	1.5	1.2	1.3	1.35	1.3	1.45	1.5	1.3	1.45	1.5
EN4	0.667	1	1	1.3	1.45	1.5	1.6	1.9	1.95	1.3	1.45	1.5	1.2	1.3	1.35	1.2	1.3	1.35	1.3	1.45	1.5	1.3	1.45	1.5	1.2	1.3	1.35	1.2	1.3	1.35
SO1	1.5	1.75	1.8	1.2	1.3	1.35	1.2	1.3	1.35	1.4	1.6	1.65	1.5	1.75	1.8	0.667	1	1	1	1	1.05	1.2	1.3	1.35	1	1	1.05	0.667	1	1
SO2	0.667	1	1	1.3	1.45	1.5	1.4	1.6	1.65	1.5	1.75	1.8	1.4	1.6	1.65	1.4	1.6	1.65	1.5	1.75	1.8	1.5	1.75	1.8	1.4	1.6	1.65	1.4	1.6	1.65
SO3	1.4	1.6	1.65	1.4	1.6	1.65	1.6	1.9	1.95	1.4	1.6	1.65	1.5	1.75	1.8	1.4	1.6	1.65	1.3	1.45	1.5	1.5	1.75	1.8	1.6	1.9	1.95	1.5	1.75	1.8
SO4	1.3	1.45	1.5	1.3	1.45	1.5	1.3	1.45	1.5	1.3	1.45	1.5	0.5	0.667	1	1.3	1.45	1.5	1.4	1.6	1.65	1.4	1.6	1.65	1.3	1.45	1.5	1.3	1.45	1.5

Table 6. Geometric Mean Fuzzy Relative Importance (S_j^-), Coefficient (k_j^-), Fuzzy Recalculated weight (q_j^-) and Fuzzy Relative Weight (w_j^-) and Defuzzified Weight (F-Weight) of the Criteria by F-PIPRECIAS method.

Criteria	G. Mean (S_j^-)			k_j^-			q_{j^-}			w_{j^-}			F-Weight	Weight (%)
AG1	1	1	1	1.00	1.00	1.00	1.00	1.00	1.00	0.040	0.028	0.025	0.030	2.99
AG2	1.290	1.431	1.482	0.710	0.569	0.518	1.409	1.758	1.929	0.057	0.050	0.049	0.051	5.09
AG3	1.139	1.344	1.382	0.861	0.656	0.618	1.162	1.525	1.618	0.047	0.043	0.041	0.044	4.35
AG4	1.384	1.573	1.623	0.616	0.427	0.377	1.623	2.341	2.654	0.065	0.067	0.067	0.066	6.64
AG5	1.264	1.388	1.439	0.736	0.612	0.561	1.359	1.634	1.783	0.055	0.046	0.045	0.048	4.76
AG6	1.416	1.622	1.672	0.584	0.378	0.328	1.712	2.647	3.053	0.069	0.075	0.077	0.075	7.45
AG7	1.334	1.578	1.621	0.666	0.422	0.379	1.502	2.368	2.636	0.060	0.067	0.066	0.066	6.61
AG8	1.492	1.733	1.783	0.508	0.267	0.217	1.967	3.744	4.618	0.079	0.106	0.116	0.104	10.36
EC1	0.771	1.031	1.129	1.229	0.969	0.871	0.813	1.032	1.149	0.033	0.029	0.029	0.030	2.98
EC2	0.749	0.990	1.130	1.251	1.010	0.870	0.799	0.991	1.150	0.032	0.028	0.029	0.029	2.90
EC3	0.927	1.130	1.204	1.073	0.870	0.796	0.932	1.150	1.256	0.037	0.033	0.032	0.033	3.33
EN1	0.691	1.031	1.130	1.309	0.969	0.870	0.764	1.032	1.150	0.031	0.029	0.029	0.030	2.95
EN2	1.374	1.559	1.609	0.626	0.441	0.391	1.598	2.266	2.558	0.064	0.064	0.064	0.064	6.44
EN3	1.231	1.417	1.461	0.769	0.583	0.539	1.300	1.716	1.854	0.052	0.049	0.047	0.049	4.90
EN4	1.202	1.374	1.418	0.798	0.626	0.582	1.254	1.598	1.717	0.050	0.045	0.043	0.046	4.59
SO1	1.092	1.268	1.307	0.908	0.732	0.693	1.102	1.367	1.442	0.044	0.039	0.036	0.039	3.94
SO2	1.317	1.553	1.596	0.683	0.447	0.404	1.465	2.236	2.473	0.059	0.064	0.062	0.063	6.26
SO3	1.457	1.684	1.735	0.543	0.316	0.265	1.842	3.169	3.767	0.074	0.090	0.095	0.088	8.83
SO4	1.199	1.368	1.468	0.801	0.632	0.532	1.249	1.583	1.880	0.050	0.045	0.047	0.046	4.63

Table 7. G.M. of Fuzzy Relative Importance (S_j^-), Coefficient (k_j^-), Fuzzy Recalculated weight (q_j^-) and Fuzzy Relative Weight (w_j^-) and Defuzzified Weight (SF-Weight) of the Criteria by SF-PIPRECIAS method.

Criteria	G. Mean (S_j^-)			k_j^-			q_j^-			w_j^-			SF-Weight	% Weight
AG1	1	1	1	1.00	1.00	1.00	1.00	1.00	1.00	0.042	0.030	0.026	0.031	3.13
AG2	1.263	1.529	1.573	0.737	0.471	0.427	1.357	2.123	2.342	0.058	0.063	0.061	0.062	6.20
AG3	1.15	1.452	1.511	0.850	0.548	0.489	1.176	1.825	2.045	0.050	0.054	0.053	0.054	5.35
AG4	1.385	1.582	1.618	0.615	0.418	0.382	1.626	2.392	2.618	0.069	0.071	0.068	0.070	7.05
AG5	1.334	1.452	1.474	0.666	0.548	0.526	1.502	1.825	1.901	0.064	0.054	0.050	0.055	5.52
AG6	1.439	1.658	1.700	0.561	0.342	0.3	1.783	2.924	3.333	0.076	0.087	0.087	0.085	8.53
AG7	1.069	1.348	1.392	0.931	0.652	0.608	1.074	1.534	1.645	0.046	0.046	0.043	0.045	4.53
AG8	1.325	1.529	1.573	0.675	0.471	0.427	1.481	2.123	2.342	0.063	0.063	0.061	0.063	6.29
EC1	1.031	1.23	1.511	0.969	0.77	0.489	1.032	1.299	2.045	0.044	0.039	0.053	0.042	4.20
EC2	0.913	1.202	1.392	1.087	0.798	0.608	0.920	1.253	1.645	0.039	0.037	0.043	0.039	3.86
EC3	0.947	1.089	1.306	1.053	0.911	0.694	0.950	1.098	1.441	0.040	0.033	0.038	0.035	3.48
EN1	0.913	1.202	1.392	1.087	0.798	0.608	0.920	1.253	1.645	0.039	0.037	0.043	0.039	3.86
EN2	1.385	1.582	1.618	0.615	0.418	0.382	1.626	2.392	2.618	0.069	0.071	0.068	0.070	7.05
EN3	1.069	1.348	1.392	0.931	0.652	0.608	1.074	1.534	1.645	0.046	0.046	0.043	0.045	4.53
EN4	1.15	1.452	1.511	0.850	0.548	0.489	1.176	1.825	2.045	0.050	0.054	0.053	0.054	5.35
SO1	1.069	1.348	1.392	0.931	0.652	0.608	1.074	1.534	1.645	0.046	0.046	0.043	0.045	4.53
SO2	1.069	1.348	1.392	0.931	0.652	0.608	1.074	1.534	1.645	0.046	0.046	0.043	0.045	4.53
SO3	1.439	1.658	1.700	0.561	0.342	0.3	1.783	2.924	3.333	0.076	0.087	0.087	0.085	8.53
SO4	0.947	1.089	1.306	1.053	0.911	0.694	0.950	1.098	1.441	0.040	0.033	0.038	0.035	3.48

According to the findings (Table 8 and Figure 2), the criteria in decreasing order of weight are: AG8>SO3> AG6>AG4>AG7>EN2>SO2>AG2>EN3>AG5>SO4>EN4>AG3> SO1>EC3>AG1>EC1>EN1>EC2. Customer driven innovation (AG8) is top ranked criteria (9.89) followed by worker's training and career development (SO3), multi-skilled and flexible workforce (AG6), delivery flexibility (AG4), collaboration with partners (AG7), green manufacturing process (EN2), and worker's occupational health and safety (SO2) criteria weight are greater than 6% and they are the most important criteria for GOP selection. The customer driven innovation for new product development is an important in fashion industry as product life is very short (Sinha & Anand, 2018). Multi-skilled and flexible workforce, delivery flexibility, and collaboration with partners will enhance supply chain agility to meet the customer demand changes (Ulutas et al., 2016; Luthra et al., 2017; Adalı & Işık, 2017; Awasthi et al., 2018; Garg & Sharma, 2020). Green manufacturing process adoption by outsourcing partner will reduce waste and energy consumption which will enhance environmental sustainability (Luthra et al., 2017; Awasthi et al., 2018; Sinha & Anand, 2018; Garg & Sharma, 2020). On the other hand, worker's training and career development (Rahman & Subramanian, 2017; Faisal et al., 2017), and worker's occupational health and safety (Luthra et al., 2017; Sinha & Anand, 2018; Garg & Sharma, 2020) will develop social sustainability.

Table 8. Criteria Weight and Rank by F-PIPRECIAS and SF-PIPRECIAS method.

Criteria	F-PIPRECIAS		SF-PIPRECIAS	
	Weight	Rank	Weight	Rank
AG1	2.99	16	3.13	19
AG2	5.09	8	6.20	6
AG3	4.35	13	5.35	8
AG4	6.64	4	7.05	3
AG5	4.76	10	5.52	7
AG6	7.45	3	8.53	1
AG7	6.61	5	4.53	11
AG8	10.36	1	6.29	5
EC1	2.98	17	4.20	10
EC2	2.90	18	3.86	15
EC3	3.33	15	3.48	17
EN1	2.95	19	3.86	16
EN2	6.44	6	7.05	4
EN3	4.90	9	4.53	12
EN4	4.59	12	5.35	9
SO1	3.94	14	4.53	13
SO2	6.26	7	4.53	14
SO3	8.83	2	8.53	2
SO4	4.63	11	3.48	18

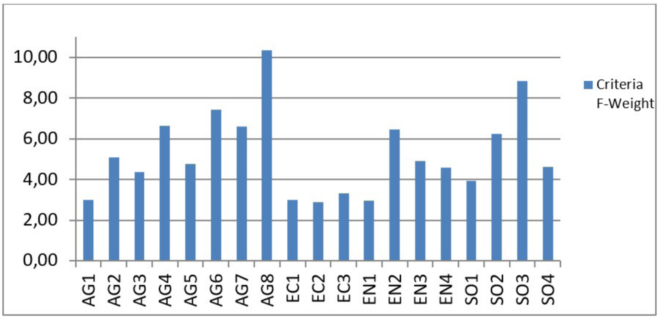

Figure 2. Criteria weight by F-PIPRECIAS method.

The service level (AG2), cleaner technology (EN3), sourcing flexibility (AG5), corporate social responsibility (SO4), environmental management system (EN4), and lead time minimization (AG3) criteria weight range 4-6% and said to be medium important criteria for GOP selection. The remaining criteria such as worker's fair wages and welfare (SO1), cost reduction (EC3), production capability & flexibility (AG1), product price (EC1), green product (EN1) and product quality (EC2) weight less than 4% and are said to be least important in GOP selection. Overall agile criteria scored 48.03% followed by social criteria 23.38%, environmental criteria 18.88% and economic criteria 9.35%. This indicates that agile criteria find high importance in GOP selection process and least importance is given to economic criteria in the case study. The adoption of agile and sustainable criteria will enhance supply chain agility and sustainability resulting into sustainable supply chain and business. According to Figures 3 and 4, the criteria weight and rank by F-PIPRECIAS and SF-PIPRECIAS are changing. This is due high variance in rating by limited number of respondents (ten) in F-PIPRECIAS method while the result of SF-PIPRECIAS is based on 100 simulations, thus variance gets reduced and offers a better smooth result. It is therefore, suggested to use SF-PIPRECIAS method for criteria priority assessment.

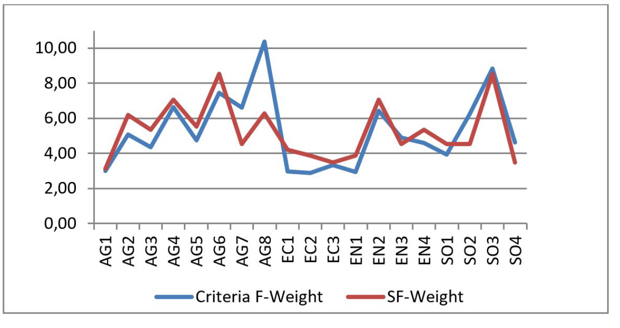

Figure 3. Criteria Weight by F-PIPRECIAS and SF-PIPRECIAS.

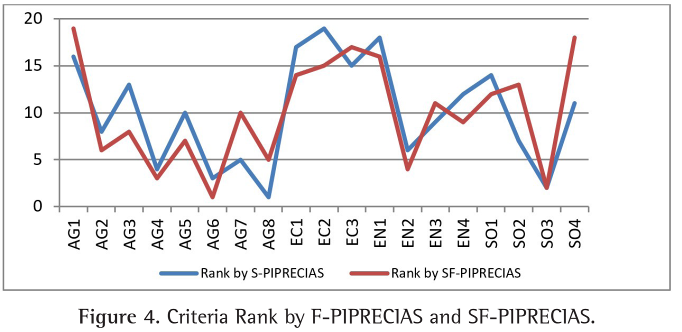

Figure 4. Criteria Rank by F-PIPRECIAS and SF-PIPRECIAS.

6.1. Implication for theory

In practice, limited number of DMs is involved in relative rating of criteria. If the number of experts or DMs can be increased, GOP can be evaluated more precisely. Stochastic approach using random number based on normal distribution will improve the performance of PIPRECIAS and MCDM methods and thus overcoming the limitations of the fuzzy or traditional MCDM approaches (Ayrim et al., 2018). The SF-PIPRECIAS is an improved method which uses triangular fuzzy numbers and random numbers to overcome the ambiguity, uncertainty and randomness in group ratings to improve the accuracy of the criteria weight. Stochastic values are calculated using random numbers, which will enhance the confidence level to determine consensus of the expert opinions (Kolios et al., 2016b). The stochastic methods proposed can be used with other deterministic or fuzzy MCDM methods such as TOPSIS, AHP, etc. (Kolios et al., 2016a).

6.2. Implication for practice

In this paper, criteria weights and ranking are determined using F-PIPRECIAS and SF-PIPRECIAS method in the case study of Indian Footwear Company for GOP selection. In the globalized, dynamic and volatile business environment, the agility and flexibility play very important role to meet the customer demand. Hence, managers in footwear firm should adopt important agile criteria for GOP selection. India is second largest producer of footwear globally, and footwear manufacturing and end of life disposal are impacting the environment. It is imperative to incorporate social and environmental criteria in global manufacturing outsourcing decisions to reduce environmental impact and enhance social sustainability in footwear industry in developing countries. The method is simple, require less number of mutual comparison and easy to use. Industry professionals can easily add or delete the criteria depending upon the situation and requirements of the firm and use the proposed model for GOP selection for accurate results in uncertain environment.

7. Conclusion

The product variety is large and having short life and competition is strong in the footwear industry. To remain competitive, many companies are outsourcing their activities including product design and manufacturing to third parties. The current business environment is volatile, uncertain and competitive. Due to climate change and global pressure, sustainability adoption is imperative in business. Therefore, sustainability and agility criteria have been incorporated to fulfill the changing customer demand and sustainability requirements for global manufacturing outsourcing partner selection which will enhance the sustainability, agility and competitive advantage of the supply chain and the firm. The importance of sustainable criteria varies from firm to firm, industry to industry and nation to nation (Silvestre, 2015). The ambiguity and uncertainty exist in group ratings. Fuzzy method capture the uncertainty and imprecision in criteria weight and alternative assessment (Ziemba, 2018). The F-PIPRECIAS method was applied to determine the relative weight and ranking criteria for GOP selection. Agile criteria have come on the top followed by social, environmental and economic in order of ranks as per this study.

The study suggests that agile criteria such as customer driven innovation, worker's training and career development, multi-skilled and flexible workforce, delivery flexibility, collaboration with partners, green manufacturing process, and worker's occupational health and safety are found to be most important criteria as per this study and therefore should be given highest priority in GOP selection process in Footwear company, which will take care of business volatility and improves supply chain agility, sustainability and performance (Barhmi, 2019). Social sustainable business operations and outsourcing practices such as worker's training and career development, worker's occupational health and safety, corporate social responsibility, and worker's fair wages and welfare should be given next priority followed by economic criteria such as product price and product quality are crucial for the company survival. Indian footwear firms should implement strategies to optimize resource utilization and cost reduction that will provide economic benefit and long-term competitive advantage. Firms need to adopt green manufacturing process, cleaner technology, EMS and green product to become more environmental friendly, cost effective and competitive (Sen et al., 2018).

It has become necessary to incorporate agility, flexibility and sustainability in operations and supply chain processes in today's globalised, dynamic and uncertain business environment. The triple bottom line (economic, environmental and social sustainability) and agility adoption requires outsourcing partners collaboration and hence their selection becomes important and challenging for the businesses. The paper presents a model using F-PIPRECIAS and SF-PIPRECIAS for criteria evaluation and ranking for agile and sustainable manufacturing outsourcing partner selection in footwear industry. The proposed model will overcome the limitations of ambiguity, uncertainty and randomness in group decision making. The study has some limitations. It was conducted with limited number of respondents from a single footwear company in a developing country. The future studies may include more respondents from larger sample of footwear manufacturing firms to generalise the finding of the study. More number of criteria may be included in future studies. Some criteria may be changed as per business need and sector. Though the study was conducted in a footwear industry, the proposed method can easily be adopted in other sectors.

References

Adalı, E. A., & Işık, A. T. (2017). CRITIC and MAUT methods for the contract manufacturer selection problem. *European Journal of Multidisciplinary Studies*, *2*(5), 93-101. http://dx.doi.org/10.26417/ejms.v5i1.p93-101.

Akhtar, M., & Ahmad, M. T. (2021). A stochastic fuzzy multi-criteria group decision-making for sustainable vendor selection in Indian petroleum refining sector. *Benchmarking*, *29*(3), 963-996. http://dx.doi.org/10.1108/BIJ-09-2020-0500.

Al-Shboul, M. D. A. (2017). Infrastructure framework and manufacturing supply chain agility: the role of delivery dependability and time to market. *Supply Chain Management*, *22*(2), 172-185. http://dx.doi.org/10.1108/SCM-09-2016-0335.

Arabsheybani, A., Paydar, M. M., & Safaei, A. S. (2018). An integrated fuzzy MOORA method and FMEA technique for sustainable supplier selection considering quantity discounts and supplier's risk. *Journal of Cleaner Production*, *190*, 577-591. http://dx.doi.org/10.1016/j.jclepro.2018.04.167.

Awasthi, A., Govindan, K., & Gold, S. (2018). Multi-tier sustainable global supplier selection using a fuzzy AHP-VIKOR based approach. *International Journal of Production Economics*, *195*, 106-117. http://dx.doi.org/10.1016/j.ijpe.2017.10.013.

Ayrim, Y., Atalay, K. D., & Can, G. F. (2018). A new stochastic MCDM approach based on COPRAS. *International Journal of Information Technology & Decision Making*, *17*(3), 857-882. http://dx.doi.org/10.1142/S0219622018500116.

Barhmi, A. (2019). Agility and responsiveness capabilities: impact on supply chain performance. *European Scientific Journal*, *15*(7), 212-224. http://dx.doi.org/10.19044/esj.2019.v15n7p212.

Blagojevic, A., Stevic, Z., Marinkovic, D., Kasalica, S., & Rajilic, S. (2020). A novel entropy-fuzzy PIPRECIA-DEA model for safety evaluation of railway traffic. *Symmetry*, *12*(9), 1479. http://dx.doi.org/10.3390/sym12091479.

Chan, A. T., Ngai, E. W., & Moon, K. K. (2017). The effects of strategic and manufacturing flexibilities and supply chain agility on firm performance in the fashion industry. *European Journal of Operational Research*, *259*(2), 486-499. http://dx.doi.org/10.1016/j.ejor.2016.11.006.

Cheraghalipour, A., & Farsad, S. (2018). A bi-objective sustainable supplier selection and order allocation considering quantity discounts under disruption risks: a case study in plastic industry. *Computers & Industrial Engineering*, *118*, 237-250. http://dx.doi.org/10.1016/j.cie.2018.02.041.

Đalić, I., Stević, Ž., Karamasa, C., & Puška, A. (2020). A novel integrated fuzzy PIPRECIA–interval rough SAW model: Green supplier selection. *Decision Making: Applications in Management and Engineering*, *3*(1), 126-145.

Faisal, M. N., Banwet, D. K., & Shankar, R. (2017). A framework for sustainable outsourcing through social collaboration: a case study of Indian manufacturing industry. *Journal of Cleaner Production*, *141*, 803-815.

Fallahpour, A., Udoncy Olugu, E., Nurmaya Musa, S., Yew Wong, K., & Noori, S. (2017). A decision support model for sustainable supplier selection in sustainable supply chain management. *Computers & Industrial Engineering*, *105*, 391-410. http://dx.doi.org/10.1016/j.cie.2017.01.005.

Garg, C. P., & Sharma, A. (2020). Sustainable outsourcing partner selection and evaluation using an integrated BWM–VIKOR framework. *Environment, Development and Sustainability*, *22*(2), 1529-1557. http://dx.doi.org/10.1007/s10668-018-0261-5.

Goker, N. (2021). A novel integrated intuitionistic fuzzy decision aid for agile outsourcing provider selection: a COVID-19 pandemic-based scenario analysis. *Soft Computing*, *25*(21), 13723-13740. http://dx.doi.org/10.1007/s00500-021-06037-0. PMid:34316288.

Goren, H. G. (2018). A decision framework for sustainable supplier selection and order allocation with lost sales. *Journal of Cleaner Production*, *183*, 1156-1169. http://dx.doi.org/10.1016/j.jclepro.2018.02.211.

Govindan, K., Khodaverdi, R., & Jafarian, A. (2014). A fuzzy multi criteria approach for measuring sustainability performance of a supplier based on triple bottom line approach. *Journal of Cleaner Production*, *47*, 345-354. http://dx.doi.org/10.1016/j.jclepro.2012.04.014.

Gualandris, J., Golini, R., & Kalchschmidt, M. (2014). Do supply management and global sourcing matter for firm sustainability performance? *Supply Chain Management*, *19*(3), 258-274. http://dx.doi.org/10.1108/SCM-11-2013-0430.

Hu, K.-J., & Yu, V. F. (2015). An integrated approach for the electronic contract manufacturer selection problem. *Omega*, *62*, 68-81. http://dx.doi.org/10.1016/j.omega.2015.08.010.

Jalao, E. R., Wu, T., & Shunk, D. (2014). A stochastic AHP decision making methodology for imprecise preferences. *Information Sciences*, *270*, 192-203. http://dx.doi.org/10.1016/j.ins.2014.02.077.

Ji, P., Zhang, H. Y., & Wang, J. Q. (2018). Selecting an outsourcing provider based on the combined MABAC–ELECTRE method using single-valued neutrosophic linguistic sets. *Computers & Industrial Engineering*, *120*, 429-441. http://dx.doi.org/10.1016/j.cie.2018.05.012.

Jum'a, L., Zimon, D., & Ikram, M. (2021). A relationship between supply chain practices, environmental sustainability and financial performance: evidence from manufacturing companies in Jordan. *Sustainability*, *13*(4), 2152. http://dx.doi.org/10.3390/su13042152.

Kabus, J., Dziadkiewicz, M., Miciuła, I., & Mastalerz, M. (2022). Using Outsourcing Services in Manufacturing Companies. *Resources*, *11*(3), 34. http://dx.doi.org/10.3390/resources11030034.

Kersuliene, V., Zavadskas, E. K., & Turskis, Z. (2010). Selection of rational dispute resolution method by applying new step–wise weight assessment ratio analysis (SWARA). *Journal of Business Economics and Management*, *11*(2), 243-258. http://dx.doi.org/10.3846/jbem.2010.12.

Kolios, A. J., Rodriguez-Tsouroukdissian, A., & Salonitis, K. (2016b). Multi-criteria decision analysis of offshore wind turbines support structures under stochastic inputs. *Ships and Offshore Structures*, *11*(1), 38-49.

Kolios, A., Mytilinou, V., Lozano-Minguez, E., & Salonitis, K. (2016a). A comparative study of multiple-criteria decision-making methods under stochastic inputs. *Energies*, *9*(7), 566. http://dx.doi.org/10.3390/en9070566.

Le, T. T., & Ikram, M. (2022). Do sustainability innovation and firm competitiveness help improve firm performance? Evidence from the SME sector in Vietnam. *Sustainable Production and Consumption*, *29*, 588-599. http://dx.doi.org/10.1016/j.spc.2021.11.008.

Liaw, C. F., Hsu, W. C. J., & Lo, H. W. (2020). A hybrid MCDM model to evaluate and classify outsourcing providers in manufacturing. *Symmetry*, *12*(12), 1962. http://dx.doi.org/10.3390/sym12121962.

Lo, H. W., Chang, D. S., & Huang, L. T. (2022). Sustainable strategic alliance partner selection using a neutrosophic-based decision-making model: a case study in passive component manufacturing. *Complexity*, *2022*(Special Issue), 9483256. http://dx.doi.org/10.1155/2022/9483256.

Luthra, S., Govindan, K., Kannan, D., Mangla, S. K., & Garg, C. P. (2017). An integrated framework for sustainable supplier selection and evaluation in supply chains. *Journal of Cleaner Production*, *140*, 1686-1698. http://dx.doi.org/10.1016/j.jclepro.2016.09.078.

Malviya, R. K., Kant, R., & Gupta, A. D. (2018). Evaluation and selection of sustainable strategy for green supply chain management implementation. *Business Strategy and the Environment*, *27*(4), 475-502. http://dx.doi.org/10.1002/bse.2016.

Nair, A., Guldiken, O., Fainshmidt, S., & Pezeshkan, A. (2015). Innovation in India: a review of past research and future directions. *Asia Pacific Journal of Management*, *32*(4), 925-958. http://dx.doi.org/10.1007/s10490-015-9442-z.

Percin, S. (2019). An integrated fuzzy SWARA and fuzzy AD approach for outsourcing provider selection. *Journal of Manufacturing Technology Management*, *30*(2), 531-552. http://dx.doi.org/10.1108/JMTM-08-2018-0247.

Prakash, C., & Barua, M. K. (2016). A combined MCDM approach for evaluation and selection of third-party reverse logistics partner for Indian electronics industry. *Sustainable Production and Consumption*, *7*, 66-78. http://dx.doi.org/10.1016/j.spc.2016.04.001.

Rahman, M. M., & Subramanian, N. (2017). Factors influencing employee training in offshore outsourcing relationships: An exploratory study. *International Journal of Human Resource Management*, *28*(6), 978-1003.

Sahu, A. K., Sharma, M., Raut, R. D., Sahu, A. K., Sahu, N. K., Antony, J., & Tortorella, G. L. (2023). Decision-making framework for supplier selection using an integrated MCDM approach in a lean-agile-resilient-green environment: evidence from Indian automotive sector. *The TQM Journal*, *35*(4), 964-1006. http://dx.doi.org/10.1108/TQM-12-2021-0372.

Sen, D. K., Datta, S., & Mahapatra, S. S. (2018). Sustainable supplier selection in intuitionistic fuzzy environment: a decision-making perspective. *Benchmarking*, *25*(2), 545-574. http://dx.doi.org/10.1108/BIJ-11-2016-0172.

Silvestre, B. S. (2015). A hard nut to crack! Implementing supply chain sustainability in an emerging economy. *Journal of Cleaner Production*, *96*, 171-181. http://dx.doi.org/10.1016/j.jclepro.2014.01.009.

Singh, P. K., & Sarkar, P. A. (2021). Multi-criteria decision approach to select contract manufacturer for sustainable development of automotive products: an integrated framework. *Process Integration and Optimization for Sustainability*, *5*(4), 843-857. http://dx.doi.org/10.1007/s41660-021-00181-8.

Sinha, A. K., & Anand, A. (2018). Development of sustainable supplier selection index for new product development using multi criteria decision making. *Journal of Cleaner Production*, *197*, 1587-1596. http://dx.doi.org/10.1016/j.jclepro.2018.06.234.

Song, W., Xu, Z., & Liu, H. C. (2017). Developing sustainable supplier selection criteria for solar air conditioner manufacturer: an integrated approach. *Renewable & Sustainable Energy Reviews*, *79*, 1461-1471. http://dx.doi.org/10.1016/j.rser.2017.05.081.

Stanujkic, D., Karabasevic, D., Popovic, G., & Sava, C. (2021). Simplified pivot pairwise relative criteria importance assessment (PIPRECIA-S) method. *Romanian Journal of Economic Forecasting*, *24*(4), 141-154.

Stanujkic, D., Zavadskas, E. K., Karabasevic, D., Smarandache, F., & Turskis, Z. (2017). The use of the pivot pairwise relative criteria importance assessment method for determining the weights of criteria. *Romanian Journal of Economic Forecasting*, *20*, 116-133.

Stević, Ž., Bouraima, M. B., Subotić, M., Qiu, Y., Buah, P. A., Ndiema, K. M., & Ndjegwes, C. M. (2022). Assessment of causes of delays in the road construction projects in the Benin Republic using Fuzzy PIPRECIA method. *Mathematical Problems in Engineering*, *2022*, 5323543. http://dx.doi.org/10.1155/2022/5323543.

Stević, Ž., Stjepanović, Ž., Božičković, Z., Das, D. K., & Stanujkić, D. (2018). Assessment of conditions for implementing information technology in a warehouse system: a novel fuzzy piprecia method. *Symmetry*, *10*(11), 586. http://dx.doi.org/10.3390/sym10110586.

Ulutaş, A., Popovic, G., Radanov, P., Stanujkic, D., & Karabasevic, D. (2021). A new hybrid fuzzy PSI-PIPRECIA-CoCoSo MCDM based approach to solving the transportation company selection problem. *Technological and Economic Development of Economy*, *27*(5), 1227-1249. http://dx.doi.org/10.3846/tede.2021.15058.

Ulutas, A., Shukla, N., Kiridena, S., & Gibson, P. (2016). A utility-driven approach to supplier evaluation and selection: empirical validation of an integrated solution framework. *International Journal of Production Research*, *54*(5), 1554-1567. http://dx.doi.org/10.1080/00207543.2015.1098787.

Vasiljević, M., Fazlollahtabar, H., Stević, Ž., & Vesković, S. (2018). A rough multi criteria approach for evaluation of the supplier criteria in automotive industry. *Decision Making: Applications in Management and Engineering*, *1*(1), 82-96.

Vesković, S., Stević, Ž., Karabašević, D., Rajilić, S., Milinković, S., & Stojić, G. (2020). A new integrated fuzzy approach to selecting the best solution for business balance of passenger rail operator: Fuzzy PIPRECIA-fuzzy EDAS model. *Symmetry*, *12*(5), 743. http://dx.doi.org/10.3390/sym12050743.

Wu, C., & Barnes, D. (2011). A literature review of decision-making models and approaches for partner selection in agile supply chains. *Journal of Purchasing and Supply Management*, *17*(4), 256-274. http://dx.doi.org/10.1016/j.pursup.2011.09.002.

Wu, K. J., Tseng, M. L., Chiu, A. S., & Lim, M. K. (2017). Achieving competitive advantage through supply chain agility under uncertainty: a novel multi-criteria decision-making structure. *International Journal of Production Economics*, *190*, 96-107. http://dx.doi.org/10.1016/j.ijpe.2016.08.027.

Yusuf, Y. Y., Gunasekaran, A., Musa, A., Dauda, M., El-Berishy, N. M., & Cang, S. (2014). A relational study of supply chain agility, competitiveness and business performance in the oil and gas industry. *International Journal of Production Economics*, *147*, 531-543. http://dx.doi.org/10.1016/j.ijpe.2012.10.009.

Ziemba, P. (2018). NEAT F-PROMETHEE: a new fuzzy multiple criteria decision making method based on the adjustment of mapping trapezoidal fuzzy numbers. *Expert Systems with Applications*, *110*, 363-380. http://dx.doi.org/10.1016/j.eswa.2018.06.008.